JPL D-4487

# Space Station User Documentation: Lessons from the Space Shuttle

**Randy Cassingham**
**Systems Analysis**

Foreword by Robert L. Staehle

June 30, 1987

National Aeronautics and
Space Administration

JPL

**Jet Propulsion Laboratory**
California Institute of Technology
Pasadena, California

# Space Station User Documentation: Lessons from the Space Shuttle

## FOREWORD

Users of complex systems are often confronted with a complex array of documentation which is essential to understanding and getting the most out the system. Space Station users and prospective users will depend heavily upon Program documentation to first decide whether and how to use the system, and then to guide them through their planning and utilization of a diverse set of flight elements, ground facilities, software and data networks. Program-to-user documentation will often be the user's most informative interface with the Program. The degree to which this documentation is clear, accessible, well-organized, accurate, and timely will directly influence the amount of user and Program resources needed for effective Station utilization.

Many users of the Space Transportation System (STS) feel that substantial improvements may be made in the way documentation was handled in terms of quantity, clarity, and accessibility. In many cases, users have found information contained in related documentation to be contradictory. In this paper, the results are presented of a survey of STS users about their experience with STS documentation. Based on these results and considerable thought and discussion of how to streamline the interface between users and the Space Station Program, a multi-level Program-to-user documentation structure is recommended. Documentation levels are related to increasing levels of commitment to using the Station, and permit a prospective user, and later an approved user during payload development, to go only as far as a well-defined level of documentation to find the needed information.

Other recommendations are made regarding the accessibility and indexing of Station-to-user documentation using the Space Station's computerized Technical and Management Information System (TMIS), and regarding the submission of User-to-Program documentation in an orderly and non-repetitive manner over TMIS.

It should be understood that not all Shuttle users participated in the survey. The valuable results which a broad diversity of users have derived from the Shuttle program speak for themselves; any criticisms contained in this document are intended in the most constructive possible manner.

The work described in this document was performed at the Jet Propulsion Laboratory for the Level I Space Station Utilization Office at NASA Headquarters. People performing the User Services Handbook, User Operations Policy, and User Operations Support Definition tasks all provided information for this document.

Robert L. Staehle
Systems Analysis Section (311)

Space Station User Documentation:
Lessons from the Space Shuttle


## ABSTRACT

This paper reports the results of a survey of Principal Investigators (PIs) regarding their experience with Space Shuttle/Spacelab systems' Program-to-user documentation. Based on earlier definition and policy studies at JPL and the survey results, recommendations are made to improve the structure and distribution of Space Station Program-to-user documentation.


## RECOMMENDATIONS

1. The Space Station Program Office must take early action to ensure that the Program-to-user documentation structure is comprehensive, concise, easily accessible, accurate, and quickly provides the user with all appropriate information at different levels of interaction with the program. A documentation control plan for all documents needs to be developed and implemented by Program management to ensure that documents are kept accurate and up-to-date.

2. The Space Station Technical and Management Information System (TMIS) should provide the capability for users to perform keyword searches of all available Program documents. A data base should list the contents of each document in detail, specify necessary prerequisite documents, indicate the date of the last revision, and provide for online ordering of printed copies of all documents.

3. TMIS should store the actual text and diagrams (in a standardized computer graphic format) of all Program-to-user documentation for investigators to download into their computers. TMIS should survey potential Space Station customers to determine which graphic standard(s) would best serve their needs.

4. All printed Program documents should be available from a single source. This source should have an adequate staff to respond quickly to requests for information and be able to provide copies of the latest update of each document from stock. The source organization should be serviced by TMIS to take orders for documents directly from the TMIS user. This organization's staff should also be well informed as to whether a particular document is "the latest" version and whether other documents are necessary to support the user's needs.

5. All documents should be identifiable by a discrete document number, be dated, contain an index, contain a clearly defined scope and purpose, and clearly fit into the overall Program-to-user documentation structure.

6. An automated log of controlled document recipients should be maintained so document users can be issued timely, automatic updates.

More specific recommendations are made in the sections on Documentation Structure and Electronic Distribution.

## BACKGROUND

One of the most frequent complaints heard from Shuttle users is the proliferation of documentation about the Shuttle system which users must obtain and the difficulty of tracking it all down. After documents are obtained, many users discover that documents often contradict each other, causing unnecessary delay and expense (Ref. 1). To confirm that these problems were and are real, and to test reaction to some solutions, Shuttle and Spacelab users were asked to complete a brief survey. (For the purposes of this paper, a Shuttle/Spacelab "user" is defined as an investigator who developed a payload to fly on the Shuttle -- meaning that he employed at least some of the available Program-to-user documentation -- whether or not the payload actually flew). Surveys from respondents who acknowledged that they did not use STS documentation were discarded. A total of 28 completed surveys were tabulated; of those, eight were from users who worked at NASA or NASA Centers and 20 were from users in the private sector (industry or university). Only North American users were surveyed. Responses are tabulated in Appendix A.

The process of developing payloads is clearly not an easy one, and users had documentation problems at the very beginning: they reported that it was difficult even finding out which documents they needed. Even NASA-employed investigators relied on "word of mouth", personal contacts and research to learn of the existence of documents. After the PIs identified the documents they needed, they found them difficult to acquire. The documents were obtained from a variety of sources, including mission and project managers, meetings, program offices, and even "inter-library loan".

Once the documents were in hand, there was disagreement on how good they were. While there was a consensus that documents were "appropriately technical" in nature and that they were generally complete, half of the PIs found that there was conflicting information among documents. Some of this information is still contradictory, one respondent noted, even after the discrepancies were pointed out. Several respondents said the conflicts in documents caused them delays or extra expenditures.

Documents were easier for the PIs to use when they had an index, were well written with a clear purpose and scope, were amply illustrated, and accurate. Documents were difficult to use when they were out-of-date, didn't have an index, had conflicting or unclear information, or were poorly cross-referenced with other documents. Other complaints were that there was much redundant and irrelevant data, the needed information was spread over too many different documents, or it was difficult to determine which document was needed.

It is clear that users were inconvenienced by Program-to-user documentation not being available from a single, centralized source and the lack of a cohesive structure to create a linear progression from the introductory documents to the specific mission documents. The result of the current system is both gaps in the information (especially when the user can't determine the existence of a document he needs) and overlaps in documents (since the lack of a structure doesn't create a clear scope or purpose for each individual document).

The respondents were unanimous that having a centralized source from which they could order any document would be extremely helpful. Also, the users were in favor of having a central computerized data base of the documents which could be searched by keyword to determine which documents would be valuable to them. Finally, users are very interested in having the text and diagrams of all documents available online for downloading directly to their computers -- a capability that would be in addition to printed copies.

The Shuttle/Spacelab system was a very complex, intricate system. The Space Station will be several times more complex. Since the Shuttle documentation structure was clearly a problem for users, it is obvious that the Space Station documentation structure must be streamlined and ordered before the Program documentation becomes a too-complex system that is not serviceable to its users.

## DOCUMENTATION STRUCTURE

An overall documentation structure has been discussed by members of the JPL Space Station User Operations Team, including participants in Program-sponsored User Operations Policy formulation, User Operations Support definition and the User Services Handbook task. A summary of this structure was first published in a description of the proposed User Operations Support organization (Ref. 2), and was presented at a review of JPL Space Station Utilization tasks by Richard Halpern on January 20, 1987.

In a recent JPL discussion paper (Ref. 3), seven levels of documentation were proposed, with each level appropriate to increasing degrees of involvement of a user or prospective user with the Program. These documentation levels are:

## Levels of Documentation

| Level | Category/Application |
|---|---|
| 0 | International Agreements: Partner agreements and memoranda of understanding. |
| 1 | General Public Information: Wide distribution glossy material for anyone having an interest in the Space Station Program. |
| 2 | General Solicitation of User Interest: Marketing-type information for soliciting interest from all categories of possible users. |
| 3 | Programmatic Utilization Documentation: Information needed to ascertain the utility and competitiveness of the Station for a particular application. Permits a prospective user to make realistic engineering, financial and management determinations of whether to seek Station resources for the performance of a proposed activity and to accurately estimate the complexity, schedule and resources required to operate a payload using the Station. |
| 4 | Technical Utilization Documentation: Information required to develop, test and certify payload equipment, get it launched, operated aboard the Station, and returned. |
| 5 | Mission-Specific Documentation: All joint user/Program documentation required to plan and conduct successful and contingency payload operations during a mission interval. |
| 6 | Experience Documentation: Questionnaires and narratives by users and Program personnel who interface with users describing their mission experience, with a focus on problems, how they occurred, how they were resolved, and how such problems might be mitigated or prevented in the future. |

The above levels are in general order of increasing detail, but are not strictly in the order of when each set of documentation would be provided to a specific or prospective user. For example, some mission-specific documentation, such as a current payload manifest, might be given to a user before issuing detailed interface specifications. These "levels" are not to be confused with STS management levels, Spacelab integration levels, or Space Station Program levels. There is no connection between the terms.

CONTENTS OF LEVELS

Most levels will contain a number of specific documents, all of which are related to a particular level of involvement for the user. The following documents (or types of documents) are seen as part of each level.

Level 0, International Agreements, are public records. Most prospective users are likely to be aware of these agreements before ever dealing with the Program. International agreements are not really documents supplied by the Program to the user, but they provide the foundation for agreements and documents that will involve users later in their lifecycle.

Level 1, General Public Information, will be circulated by a number of sources (certainly from each of the Partners), and will consist at a minimum of a brochure showing what the Station looks like and summarizing its capabilities and benefits. Educational publications, NASA SP-series books, and a variety of more specific brochures and booklets would fall into this level.

Level 2, General Solicitation of User Interest, is likely to involve the distribution of marketing-oriented documents by the Space Station Program Office. An outreach pamphlet and an investigator's guide are presently under development under the sponsorship of the Level I Utilization Office. User discipline codes might also create "marketing" documents, but these would not necessarily be under the direction or sponsorship of the Program.

Level 3, Programmatic Utilization Documentation, is where serious prospective users get their first thorough exposure to the Station's capabilities, limitations, and the responsibilities of the Program and users. This is where an organized structure and a coordinated dissemination method begin to truly benefit the prospective user. The documentation in this level describes the Space Station Program, gives a summary of how the Program is organized, who the Partners are, what the partners' various ownership interests and responsibilities are, and how the different parts of the Program and outside organizations (such as contractors, NASA codes, and Partner agencies) interact. Prospective users need to have this information to effectively navigate through the Program and to understand what different people are telling them. No such organized summary is presently provided to prospective Shuttle users, though the information can be gleaned from a number of sources.

Level 4, Technical Utilization Documentation, includes very specific information about standardized elements, services and utilities. Documents dealing with exact interface specifications, subsystem descriptions, operational requirements and safety requirements would be included in this level.

Level 5, Mission-specific User/Station Documentation, includes mission manifests, requirements for compatibility with other payloads, integration plans, and other custom-generated documents for each mission interval. As the mission nears its start date, such documents may change as often as daily and may only be available online through TMIS.

Level 6, Experience Documentation, would be completed by the user after the end of his mission interval. It would describe successes, failures, and, most importantly, the lessons learned that might benefit future users.

## DOCUMENTATION CONTROL

For each document within this structure (including any added later), an originator and control point needs to be specified. Different portions of a particular document may originate from several offices, in which case multiple levels of control may be required (perhaps through a normal hierarchical signature tree) leading up to the single office responsible to the rest of the Program for origination and maintenance of the document.

The originator of each document should be responsible for that document's maintenance throughout the life of the Program, as all documentation will need to be updated from time to time. Accurate and timely updates will be especially important for documentation specifying user interfaces and for all mission-specific documentation, the latter of which may change on a daily basis.

All Program-supplied documentation needs to be consistent to avoid user confusion and surprises for system operators. There may need to be a high level "consistency control point" responsible for all Station-to-user documentation. This should be considered as a possible responsibility for some part of a User Operations Support organization, which could remand conflicting language to the originators and their respective control points for removal of any inconsistency. For example, a safety document might specify a peak load of 5 amperes for a particular type of electrical connector while an interface specification document might cite a peak load of 4 amperes. Both might be ambiguous regarding the meaning of "peak load", with the writers of the safety document meaning instantaneous load and the writers of the interface specification meaning loads lasting for less than 30 seconds. The manager responsible for consistency control would direct that the two groups of originators work out a solution to make the two documents consistent. Upon agreement of the two originators, any control points between them, and the top-level consistency control point, one or both documents would be changed as agreed to make the documents consistent.

It is doubtful that any consistency check will be absolutely thorough. Therefore, users and other people who work with the documents are likely to find occasional inconsistencies. A very simple and clear method should be established for reporting such inconsistencies, or even portions of documents which are simply confusing. This could take the form of a "tear out" one-page problem report in each document which lists the address and telephone number of the office responsible for consistency control. Rapid problem reporting should be encouraged with reporting to a single collection point. As we have seen at JPL (Ref. 1), users can spend a great deal of time and money building hardware to a particular documented specification which they believe to be accurate, only to find out at the launch site that the specification was incorrect, requiring a costly delay or a hasty reconfiguration. Consistency control would review each reported problem, determine if corrective action is necessary, and notify the user of the result of his criticism.

Finally, to facilitate the exact identification of various documents, each discrete publication should be issued a document number by the consistency control point. Each document, and preferably each page in

rapidly-changing documents, should be dated so it is clear to the reader which particular version is the most recent. In addition, a printed list of all documents should be published for the users.

ELECTRONIC DISTRIBUTION

Survey results show that users are enthusiastic about having a detailed, keyword-searchable online listing of all available user documents. This searching could be used to determine which documents are required. For example, a materials processing experiment investigator could enter the key "toxic substance" and get a complete list of documents describing safety requirements for the handling of toxic reagents. Cross-referencing might suggest to the investigator that he needs to review documents describing special launch vehicle requirements for hazardous materials, waste containment systems, etc.

Additionally, these survey respondents agree that the storage of the actual text and diagrams from these documents online (in a specific, standardized computer graphics format) to allow immediate downloading into their computers would be very helpful. While most users will want to have printed copies of most documents, having the latest versions available online would allow a user to immediately access updates. For example, if a user is building his payload and discovers that the diagram on an electrical interface connector is ambiguous or out-of-date, he could access the interface document online and download the section, with diagrams, that deals with the connector in question. This capability could save countless hours or days of waiting for updates -- and the associated costs involved.

The Technical and Management Information System (TMIS), which is currently being implemented, will tie together all NASA centers and all Space Station users. Such a widely available network would be an ideal place for the online documents to be stored. TMIS planners, during their fact-finding interviews at NASA centers, have been informed that this type of documentation support would be useful. TMIS already has plans for the graphic capabilities necessary to store document diagrams and illustrations. The system should also be able to log orders for specific documents; such orders should be filled from the source without further effort by the user.

These requirements should be quite easy to fulfill, considering the current state of commercial computer network services. For example, the Dow Jones/News Retrieval Service and the CompuServe Information Service each have several hundred thousand subscribers who can use the service's standardized front end to search through numerous databases and download text and graphics using a number of error-resistant protocols.

USER-TO-PROGRAM DOCUMENTATION

In addition to finding Program-to-user documentation online, users should be given the capability to transmit user-to-Program documentation via TMIS. This could be facilitated by "interactive documentation" approaches where the user would answer online questionnaires or utilize text generators to create standardized documents (the Payload Integration Plan (PIP) is a prime example of such a "boilerplate" document). Printed copies would then be generated for formal approval and signatures.

The implementation of a "payload engineering database" on TMIS would allow users to submit technical design and operations information in one format and only one time. Once submitted, different parts of the Program would then be able to access (with appropriate protection of confidentiality) specific information they need without requiring additional input from the users.

ACKNOWLEDGEMENTS

The research described in this paper was performed by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

The author of this paper wishes to acknowledge the following individuals for their contributions to the ideas in this paper: Jackie A. Giuliano, Jeffrey S. Keys, Paul K. Henry, and M. Laura Crary. The author would particularly like to thank Robert L. Staehle, who provided much of the material contained in the sections on Documentation Structure, the Contents of Levels, and Documentation Control.

REFERENCES

1. M. Laura Crary, Lessons for the Space Station: JPL's Perspective on the Shuttle Payload Process, JPL Internal Document D-3891, March 1, 1987.

2. Jackie A. Giuliano, Proposed User Operations Support Concept for Space Station, JPL (unnumbered internal discussion paper), January 20, 1987.

3. Robert L. Staehle and Randy Cassingham, Proposed Structure for Space Station User Documentation, JPL (unnumbered internal discussion paper), March 26, 1987.

APPENDIX A
Survey and Responses

Note: Not all answers add up to the total number of respondents. Non-responses were not recorded; answers to open questions (such as "what made documents more useful") sometimes had several responses -- all of these were recorded. Some comments are paraphrased, but reflect the respondents' intentions.

Total Responses:

NASA PIs /8
Non-NASA PIs /20

Number which requested summary of findings:

NASA PIs /4
Non-NASA PIs /12

---

Questions

1) Did you find that STS documentation, in general, was complete? Were all the topics you needed information on covered in sufficient detail?

Yes /22
- -- but it was spread over too many documents /2
- -- but not easily understood /2
- -- but the information is so scattered, it is difficult to find specific references
- -- but we also could have used an approved materials list
- -- but it was not kept up-to-date
- -- the documentation may be complete, but is chaotic. Needed info may be contained in the document but it is not easily picked out
- -- but further telephone clarification was frequently required
- -- but only if you know in advance what to look for

No /4
- -- not sufficient on coordinate systems and positions of remote manipulator arm. Not good on OANC tapes
- -- background operational information was often fragmentary and confusing
- -- but this has probably improved since our early flight
- -- some particular information was lacking

---

2) Did you find that information in documents was generally

Needlessly technical /4
Appropriately technical /19
Not technical enough /1

---

3) Did you ever find conflicting information in documents that caused problems for you? Did those problems cause delay or extra expenditures?

Yes /13
- -- conflicting information did cause extra delay and expenditure /2
- -- though the conflicts didn't cause problems /2
- -- usually had to verify with MSFC, which caused delays
- -- some is still contradictory even though contradictions were pointed out
- -- there were several occasions when the description from the control document differed from the instructions from the payload ops group
- -- considering the scope of the documentation, I think they've done well in this area
- -- much too much overlap in documents, causing extra expenditure in resolving conflicts
- -- especially if you weren't careful to keep up-to-date
- -- especially between NASA centers

No /13
- -- but insufficient information and TBDs caused delays
- -- but only if you were sure to have the latest updates

---

4) In general, what made documents more useful?

Well written /6
An index /5
Good introductory material /3
Illustrations /3
Accurate
Good descriptions
Complete table of contents
Listing of contact personnel who could clarify ambiguities
Clear statement of purpose and scope
Status of revision
A NASA-assigned "book manager"
Examples
Less emphasis on "NASA idioms"

---

5) In general, what made documents difficult to use?

Too much irrelevant data /6
Info contained in too many different documents /4
Too many PIP annexes /2
Not clear whether document was current or not /2
Change control difficult to follow /2
Too many acronyms /2
Bulky size /2
Ambiguous language /2
Out of date
No (or poor) index
Conflicting/unclear information
Lack of a central distribution point for documents
Too many TBDs
Poor cross-referencing

Not written with the reader in mind
Difficult to get late changes in payload accommodations documentation
Frequent changes impacted already completed work
The multi-level paragraph numbering system (eg 3.4.42.7.80...)
Didn't contain the data they were supposed to
Our main document wasn't completed by the time we needed it
Large number of updates
Difficult to understand the document hierarchy
Too much needless jargon
Not written with the user's requirements in mind
Contradictions between documents
Finding the right document
Different documents from different centers use their own conventions, making the documents inconsistent in presentation
Other documents were referenced only by number, making it difficult to determine whether they were needed or not

---

6) Where did you find out about which documents you needed?

Miscellaneous NASA personnel /9
Cross reference from other documents /6
 -- but this is insufficient
Program or project office /5
Payload Integration Manager /4
Launch Site Support Manager /2
Investigator's Working Group (IWG) meetings /2
 -- it was too casual; I didn't get all required documentation
Word of mouth
Miscellaneous NASA personnel
Technical monitor
HQ Customer Services Rep

---

7) How did you obtain the documents you needed? Was the documentation you needed easy to obtain?

Miscellaneous NASA personnel /6
 -- but some people tend to be quite possessive of large, important, hard to obtain documents
 -- we didn't always get the documents we asked for
PIM/LSSM /4
 -- documents were easy to obtain, but I had to generate most of the technical detail myself
Easy to find once you knew what you needed /4
Ordered from JSC /3
 -- but we often didn't get what we ordered
 -- usually received documents within a week
NASA Program Office /2
 -- this sometimes was time-consuming
IWG meetings /2

Project or mission manager
 -- but docs were not easy to obtain
Through inter-library loan
 -- this was not an easy process
Not sure how we got them, but we did get them fairly easily

---

8) Would it be helpful to you if all documentation was available from a single source?

Yes /22
 -- this is imperative /3
 -- but would not be good for flight operations documents
 -- but I don't think it's likely to happen
 -- especially when you want to update distribution lists

Probably /5
 -- needs to be well-organized to respond quickly
 -- but it would be equally helpful if several different organizations had documents if they all followed similar procedures

---

9) Were you aware of exactly what documentation was necessary or required reading?

Yes /8
 -- but personal contacts were essential to determine which documents were applicable
 -- but we only really used one main document (SPAH)
 -- but a long, tedious learning process was required
 -- but it required some consultation to be sure
 -- but only after research

No /20
 -- but it got easier when we gained experience
 -- since no effort was made to provide us a list of documents
 -- but I think this is improving
 -- I still don't know

---

10) Would it be helpful to you if there were an indexed list of available documents online in a database?

Yes /24
 -- also should have summary or abstract /5
 -- this is imperative /2
 -- should also be available in printed form /2
 -- this would be extremely helpful
 -- but not especially helpful for me
 -- the database must be kept up-to-date

Probably /2
 -- at least a printed list is necessary

---

11) Would it be helpful to you if the actual text of the latest versions of each document was on line, available for downloading to your computer?

Yes /22
-- but only if in addition to paper form /3
-- all users should be given access; on STS, passwords were often changed without notification
-- but we are concerned about downloading time which may be necessary
-- this would be most helpful
-- this is imperative
-- but not especially helpful for me
-- may be impractical
-- a great idea

Probably /2

No /3

---

12) What comments and suggestions do you have to help make future Space Station documentation more useful?

Reduce the number of documents /4
Have specialists available for telephone consultation /3
Publish an introductory document which guides the user through needed documentation and references /3
Have documents available online /2
Publish a list/index of all documents /3
Simplify the language used /2
Better documentation structure/organization /2
Should be uniform in design and use /2
Have all documents available from a single source /2
Documents should be issued in loose-leaf form and be frequently updated with update pages
Replace entire document rather than issue update pages
Issue updates in a timely manner
Computer indexing of documents for searching on a particular topic
Use an easier-to-read typeface
Make it clear what documents are needed and how to get them
Keep them up-to-date
Make them more easily available
Listen to the problems we have outlined in the past
Better guidelines for which materials are approved
Categorize and simplify as much as possible
Have indexed database available
Publish an easy-to-use guide to all documentation and send it to everyone

---

13) Please list (on the reverse or on a separate page) the primary STS documents which you used in preparing your payload for flight aboard the STS. If appropriate, note those documents which you found most helpful or difficult, and why.

(responses not tabulated)

14) Would you be interested in providing more detailed information in a telephone or face-to-face interview?

Yes /12

No /9
-- not enough time!
-- too busy doing NASA paperwork
-- I don't think I would be helpful